Dr Allen Thomson

with the Author's kind regards

(16).

ON THE

Structure

OF THE

MUCOUS MEMBRANE OF THE STOMACH.

From the Gulstonian Lectures for 1839, *delivered at the Royal College of Physicians in London,*

BY R. B. TODD, M.D. F.R.S.

Fellow and Censor of the College; and Professor of Physiology, and of General and Morbid Anatomy, in King's College, London.

[FROM THE LONDON MEDICAL GAZETTE.]

by directing a stream of water upon the surface: let the whole mucous membrane be well washed under a large stream flowing from a cock, and then with a good syringe direct a moderate stream upon each portion of the membrane in succession; by these means in a short time the layer of mucus may be very completely removed, and then the stomach may be kept in a weak spirit for an indefinite period, without suffering any alteration in its structure. I have in this way preserved for many months several injected and non-injected specimens, which completely retain their natural appearance, and will, I have no doubt, continue in the same condition.

Thus prepared, the structure of the membrane may be ascertained by various modes of examination. A portion of it injected or otherwise, pinned on a piece of cork, and illuminated by light thrown upon it by a condenser, may be examined under water by the simple or compound microscope, and with the aid of a lens, or object glass, of even very low magnifying power. I find that the Coddington lens, or in the compound microscope an object glass of two inches focal distance, affords a most satisfactory view of the surface, arranged as I have stated. In a successful injection the mode of distribution of the capillaries is beautifully seen, but they are so numerous as to conceal the arrangement of the membrane, and, therefore, the anatomist must not confine himself to the examination of injected specimens only. Thin vertical sections of the membrane must next be made, and if these be sufficiently thin they may be examined as transparent objects; but the structure is very well seen when they are placed on a black ground, and examined as opaque objects. I have found it also extremely useful to make very thin horizontal sections at various depths of the membrane, and to examine them by transmitted light. This mode of examination, which has not, so far as I know, been adopted by other observers, has enabled me to satisfy myself about several points in the structure which without it must have remained doubtful.

When a portion of the mucous membrane of a true digestive stomach is examined, stretched upon a plane surface under water, we observe it to exhibit a multitude of small cells more or less circular in form. These cells are present over the whole surface, where a thick epithelium visible to the naked eye does not exist, and their presence may be considered to be characteristic of the true digestive surface, as contra-distinguished from that of a simple macerating cavity. When the mucus has been well cleared away, we can see to the floor of each cell, which exhibits from three to five perforations, often rendered distinct by being filled with the white mucous secretion (fig. 1.) The cells are separated from

FIG. 1.

This figure (from Bischoff) represents the cells seen on the surface of the stomach, with their floors perforated by the orifices of the tubes.

each other by partition-like elevations of the membrane, which vary in depth, and sometimes even form pointed processes, mistaken by some anatomists for villi, which they really do resemble when examined on an oblique section. The diameter of the cells is about 1-180th inch to 1-250th inch: it varies, however, in the different regions, and is always largest near the pylorus. Such is the general description of the mucous surface of the stomach of the following animals in which I have examined it—in man, the dog, cat, lion, the fourth stomach of ruminants, in the pig, rabbit, horse, and ass; in the simple stomachs of the frog and waternewt, in the stomach of the turtle, and in those of the skate and cod, in the former of which each cell measured 1-360th of an inch.

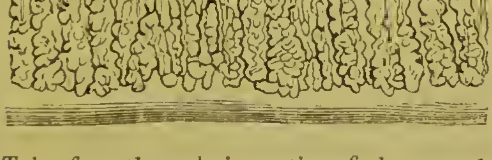
When the vessels of the stomach have been minutely injected with the size injection coloured red, nothing can be more beautiful than the vascular net-work which is then seen on the surface of the mucous membrane. The margin of each cell is surrounded by a vascular circle, which is joined at various points of its circumference by minute vessels emerging from the substance of the membrane (fig. 3), and all the circles anastomose with each other. I know nothing which more forcibly exhibits the intricacy of the capillary vessels themselves than this vascular network on the surface of the gastric mucous membrane.

Although the appearance which I have described is rendered visible by a lens of very low magnifying power, so low as three or four diameters, no trace of it can be seen by the naked eye. The orifices of the so-called gastric glands, which Sir Everard Home states may be seen at the pyloric and cardiac portions of the mucous membrane of the stomach of man and other animals, can correspond to nothing but the cells which I have described; yet it is difficult to imagine, if he really did see these cells at the cardia, how he could have avoided seeing them, similar in arrangement although different in size, all over the mucous surface. Not unfrequently a remarkable series of smaller

wrinkles is seen on the pyloric and cardiac portions of the membrane. Three slight and very short fissures radiate from a central depression, and these occur in so great numbers, and at such regular distances from each other, that they are not unlikely to be mistaken for a peculiar structure, nor to be set down as glands, by those who are zealously in search of a distinct series of such organs in connection with the stomach. I have seen this appearance many times on the human stomach, and always in that of the pig; and I am disposed to think that it is produced by the contraction of the muscular coat, although I am unable to explain exactly the manner in which it is effected.

When thin sections of the mucous membrane, cut vertically to the surface, are placed under the microscope, they are seen to be composed of a number of tubuli closely applied to each other side by side, their blind extremities being in contact with the submucous tissue, and their free extremities opening into the bottom of the cells. In some situations these tubuli are straight and short; in other parts they are longer, and at their blind extremities present an appearance which might arise either from a slight convolution of the tube, or from some irregular dilatations of it in that situation (fig. 2). It very commonly

FIG. 2.

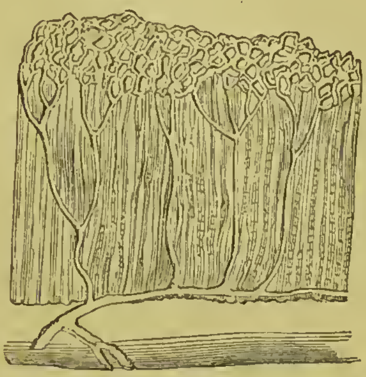


Tubes from the pyloric portion of the stomach, as seen by a vertical section.

happens that two tubuli coalesce or anastomose at their free extremities, and they will consequently open upon the floor of a cell by a common orifice; and hence it is that a greater number of tubules actually pour their contents into a cell, than would be indicated by the number of openings which pierce its floor. The diameter of the tubuli varies from 1-360th to 1-540th of an inch.

The tubuli are straiter and shorter at the cardiac portion of the stomach, longer and more convoluted, or irregular, at their blind ends, at the pyloric portions. In a vertical section of an injected specimen, we see the vessels coming up from the submucous tissue, and passing between the tubuli, as in the annexed figure (fig. 3),

FIG. 3.

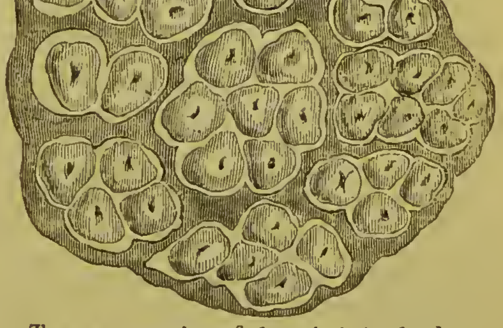


Vertical section of the mucous membrane, shewing the vessels passing to the superficial network (from Bischoff.)

to terminate in the vascular net-work on the surface.

From the examination of thin horizontal sections at various depths of the membrane, I have ascertained that the tubuli are arranged in bundles or groups, surrounded and bound together by a fine cellular membrane, the bundles varying in size, and in the number of tubules contained in them, as shewn in fig. 4, which

FIG. 4.



Transverse section of the tubuli in the dog.

represents such a section of the dog's stomach, magnified about 100 diameters.

When a very thin horizontal section, taken from the free surface of the membrane, is placed under the microscope, the free surface being upwards, and covered with talc or thin glass, a very beautiful view of the mouths of the cells, and the arrangement of the membrane around and

between them, is obtained. When viewed with an object-glass of a quarter of an inch focus, the membrane surrounding each cell appears raised, so as to form around each cell a prominent circle, from which the membrane inclines downwards into the cell; and if the section have gone below the level of the floors, we can see that the membrane is continued to the perforated floor of each cell.

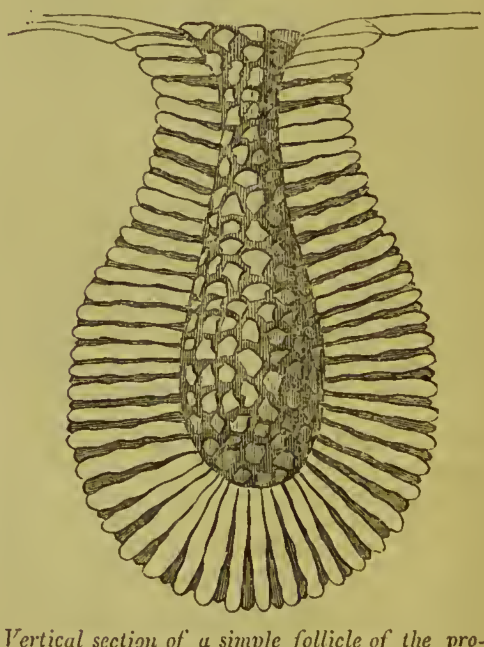
From similar sections we are enabled to see very clearly the arrangement of the epithelium on the surface. I have already stated that the absence of a thick epithelium, visible to the naked eye, is characteristic of the true digestive stomach. An epithelium, however, nevertheless exists, of a very definite arrangement, which is distinctly brought into view by the use of high powers, of a quarter and eighth of an inch focus, and we are indebted to Henle for the first complete demonstration of the existence of an epithelium upon the whole mucous tract, from the mouth to the anus. My observation, however, does not confirm the statements of this anatomist with respect to the gastric mucous membrane: I have never seen the cylindrical form of epithelium in any part of the stomach. The whole surface of the membrane, on the contrary, appears to be as it were covered with a pavement of fine polygonal epithelium scales, which under the highest power present an appearance very similar to that of shagreen. The scales not only occupy the space between the cells, but pass over their margins, and are continued down to their floors. The diameter of the scales, in the dog, in the cardiac portion of the stomach, was from 1-2325th to 1-3100th of an inch. These scales resemble very much those of the deep layer of œsophageal epithelium, both in form and dimensions.

The matter contained in the tubuli appears to be of a very different nature from the scales of the epithelium: it is a soft, whitish substance, composed of minute granules, which exhibit no trace of structure even under the highest powers. This matter may be readily obtained by pressure from the tubes, in which it always exists in considerable quantity: it is in every respect the same as the layer of mucus which covers the membrane of the recent stomach.

In my examination of the stomach of the porpoise I observed that the mucous membrane of the second and third cavities was destitute of cells; it nevertheless is composed of vertical tubes similar to those found in the digestive stomach of other animals; a structure first noticed by Cuvier, and subsequently described by Sir David Brewster. These tubes, then, instead of opening into the bottoms of cells, open at once upon the surface. Their mean diameter is 1-360th of an inch: they are long in proportion to their diameter, and straight, not exhibiting the convoluted or irregular appearance at their blind extremities, which we have noticed in the carnivorous stomach. On an injected portion of the membrane the vascular circles were seen of a similar nature to those before described. The mucous membrane of the fourth stomach exhibited cells of an oval form, 1-1538th of an inch wide, and 1-1025th of an inch long. The cells were shallow, and the tubes short and indistinct, excepting at the termination of the membrane where it passes into that of the fifth cavity: here the tubes were distinct and long, and in the fifth stomach they acquire the same characters which they possess in the second and third.

The structure of the mucous membrane of the proventriculus, or true digestive stomach of birds, demands a separate description. Here it will be recollected the membrane presents a multitude of large follicles, which open into the cavity of the proventriculus. Each follicle may be considered as a little stomach in itself: when a simple follicle is laid open in its long diameter we observe a number of minute orifices on its internal surface, which are those of a series of tubuli arranged side by side, and vertically to its wall. The annexed figure (fig. 5) is a diagram repre-

Fig. 5.



Vertical section of a simple follicle of the proventriculus in the pigeon.

senting a vertical section of one of these follicles in the pigeon: the tubes in this bird are all short and straight, and measure in diameter from 1-540th to 1-720th of an inch. The free surface of the membrane

lining the cavity of the proventriculus is covered by a delicate epithelium; the scales of a less distinct character than usual, polygonal, but with one or two of the angles rounded off.

The follicles of the proventriculus of the ostrich are of the most complex kind: into each follicle a series of smaller and simple follicles pour their secretions, so that one of these compound follicles may be said to represent on a small scale the proventriculus of the pigeon. Each of the smaller follicles has exactly the structure of the simple follicle of the pigeon. The compound follicle, then, consists of an aggregate of simple follicles placed side by side, and vertically to the walls of the large ones, whilst each simple follicle consists of an aggregate of tubuli as before described. The epithelium is very distinct on the surface of the proventriculus, on which also there are numerous triangular processes not unlike villi.

From the preceding description of the structure of the mucous membrane of the digesting stomach in the vertebrata, we may not improperly designate this membrane as a gland; its constituent tubes being arranged perpendicularly to an extended surface, and pouring their secretions into a number of cells; not, as in other glands, into one or more canals or ducts.

The change which the food undergoes in the stomach has long been known under the name of *chymification*; it consists in a total breaking down of the substance of the alimentary materials, into a soft semi-fluid mass, in which the natural texture and chemical compositiou of those substances are altogether changed. Albumen, for example, when introduced in a fluid state into the stomach, is first solidified, and then brought back again to the fluid state, from which it is not capable of being again solidified, or at least as completely as before. And starch, which has been thus acted upon in the stomach, is, according to Tiedemann and Gmelin, converted into gum of starch and sugar. Gelatine, moreover, loses, after digestion in the stomach, its property of gelatinizing spontaneously; the various forms of animal and vegetable food become so broken down and dissolved as to be no longer recognizable; moreover, when substances are of such a nature as to resist the influence of the powers of the stomach, whatever they may be, they generally pass through the intestinal canal comparatively unaltered, inasmuch as there is no part of that canal in which they meet with the same solvent or reducing principles as are found in the stomach.

It is well known that the chymifying powers of the stomach have been from an early period ascribed to the influence of a special secretion, from the walls of the organ; an hypothesis first advanced and in a great measure proved by Reaumur, whose observations were published in the year 1752, in the memoirs of the Académie des Sciences; Reaumur's views were shortly afterwards confirmed by Spallanzani and Stevens, and subsequently by John Hunter; and within the present century have received the most ample confirmation from a great number of sources, of which I may mention Tiedemann and Gmelin in Germany, Dr. Prout in this country, and Dr. Beaumont in America. This fluid, the *gastric juice* of authors, is always acid, and when removed from the body aud placed at a temperature of 100°, exerts a similar power over the alimentary substances submitted to it as in the stomach. It became important, therefore, in order to determine to what the solvent powers of this secretion were due, to ascertain its chemical constitution; and although the present imperfect state of organic chemistry scarcely enables us to determine, with perfect certainty, the true constituents of this fluid, it may be stated as the most probable result of the various analyses to which it has been subjected, that the gastric fluid contains water, with various neutral salts, free muriatic and probably also acetic acids.

Various experiments were instituted with a view to ascertain how far fluids, formed artificially in imitation of the gastric juice, would produce similar effects on the different kinds of food, which accordingly were subjected to the action of various chemical mixtures, containing acetic and muriatic acids alone or together, more or less diluted; and the negative result at least was obtained, namely, that no artificially formed fluid appeared to act upon the alimentary substances submitted to them, at all in the same way that the gastric fluid does. Whilst experimentalists succeeded perfectly in producing artificial digestion, by the aid of the gastric fluid taken from the stomach, they entirely failed when they had recourse to artificial fluids, made in imitation of the natural secretion.

To a German physiologist, Eberle, author of an interesting work on digestion*, we owe the discovery of the cause of the failure in these experiments, and I cannot but regard his discovery as one of the most important of modern times. Having failed in a great variety of experiments on artificial digestion, with a view to ascertain the cause of failure he applied himself to investigate the condition of the stomach during the chymifying process. He was struck with the large quantity of

* Physiologie der Verdauung nach Versuchen auf naturlichem und kunstlichem Wege. Wurzburg, 1834.

mucus which is always poured out upon its surface as well as upon that of the food, during that process. In the latter situation Eberle had observed the mucus adhering to the surface of the mass of food, in the form of an expansion so like the membrane of the stomach that he at first supposed it to be that membrane removed with the food; he found that this mucus existed in greatest abundance at the earlier periods of stomach digestion, and that in the later periods it became subdivided, and portions of it were mixed with the food. When the alimentary matters are chiefly of a fluid nature, this mucus was not so readily detected, from its being diluted and mixed to a greater extent with the contents of the stomach. The mucus deposited during digestion is of a greater consistence than that which ordinarily lubricates the gastric surface; it is invariably acid, and these characters are found in the true digesting stomach, whether in the simple carnivorous form, or in the fourth stomach of the ruminant, or the proventriculus of birds.

This mucus diffuses readily in water, forming a thin acid fluid, by the action of which Eberle had the satisfaction of finding that fibrin, coagulated albumen, casein, &c. were in a short time completely chymified; substances which he had hitherto failed in affecting by any of the artificial mixtures containing the acids of the stomach. In fine, this mucus is the substance which we have already described as being poured out by the vertical tubes of which the mucous membrane consists, and it is to the organic principle which it contains that the acid secretion owes its solvent powers. The failure in former experiments was due to the non-existence in the artificially formed fluids of the organic principle derived from this mucus. Schwann, who has performed a very complete series of experiments on artificial digestion, gives to this principle the name of *Pepsin.*

A fluid possessing similar powers to that just described may be easily made by infusing in distilled water a portion of rennet (fourth stomach of the calf), previously well washed, and adding some muriatic acid. I find that the following proportions answer extremely well; six grains of rennet carefully washed till all acid reaction has ceased, two drachms of distilled water, and six drops of muriatic acid. The following experiment, which I have several times repeated and shown, will serve as an illustration of the powers of this liquid. Two drachms of the fluid, prepared according to the formula above given, were put into a test tube, and small pieces of raw beef and mutton, together with a portion of boiled white of egg, cut in a cubic form, were immersed in it. Into a second test tube two drachms of distilled water, three drops of muriatic and three drops of acetic acid, and pieces of the same alimentary substances, were put; and in a third tube the pieces of meat and albumen were immersed in two drachms of distilled water, to which were added six drops of muriatic acid. The three tubes were kept for twelve hours at a temperature of 100° Fahr., and at the end of that time the following were the changes noticed in the albumen and meat. In the first test tube the albumen was reduced to a complete pulp; the meat was similarly softened, so that all appearance of its proper texture had completely vanished, and it broke down under the slightest pressure. The rennet also was completely disintegrated. In the second tube the cube of albumen had acquired at the edges a beautiful transparency, and here it had become almost of a fluid consistency: it was also very much softened in the centre. The meat was greatly softened, as in the first tube, gelatinized on its surface, and the rennet was reduced to a pulp. In the third tube no change had taken place beyond that which was evidently the result of the imbibition of fluid by the portions of meat and albumen.

The digestive fluid may be prepared by infusing the rennet in distilled water and muriatic acid, in the proportions already stated, at a temperature of 100°, for twelve hours: it must then be strained, and set aside for use. A clear straw-coloured fluid is thus obtained, exhibiting a decided acid reaction, with an agreeable smell, and not unpleasant flavour. This fluid will keep for a considerable period. I have some now by me which has kept unchanged for twelve months, and which shows no disposition to change. The digestive power of this liquid is destroyed if it be subjected to boiling, and likewise if it be neutralized by the addition of alkali, but it recovers its power again if the acid be restored. I am not without hope that it may be found useful as a therapeutic agent, in assisting the chymifying powers of the stomach, but my experience of its effects has been too limited to enable me to speak with confidence on this point.

Time warns me that I must content myself with this brief allusion to the observations of modern physiologists, which, as it appears to me, lead to the conclusion that the great agent of stomach-digestion is the secretion which, under the influence of appropriate stimuli, is poured out from every point of the mucous membrane of the physiological stomach.

Wilson & Ogilvy, Printers, 57, Skinner Street, London.